STUDYING THE EFFECT OF FOREST FIRES ON NIGHT-TIME LIGHTS USING SNPP-VIIRS-DNB AND MODIS PRODUCTS

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ABSTRACT: Night-time lights (NTL) captured by satellites contain the signals from temporary fires (e.g. forest fires) and thus NTL imagery have been used by the researchers for monitoring the forest fires. However, for studying the socio-economic development, stable NTL imagery are needed. The present study aims to investigate the effect of forest fires on the average monthly radiance products of Suomi-National Polar-orbiting Partnership - Visible Infrared Imaging Radiometer Suite - Day/Night Band (SNPP-VIIRS-DNB), generated by National Oceanic and Atmospheric Administration (NOAA). Forests in Nilgiris and Kanyakumari districts of Tamil Nadu State in the southern India are taken as the study areas. The daily forest fire locations are derived from MODIS Near Real-Time (NRT) active fire data of February to May, 2014. It is observed that the maximum occurrences of forest fires are in the months of March and April. The 'sum of lights' (SOL) derived from average monthly radiance values of monthly NTL products of February to May are studied with the number of fire occurrences for the two study districts. Good correlation between the monthly fire occurrences and SOL is observed. Point based statistics in terms of percentage change in monthly radiance and coefficient of variance also show increase in radiance values on the locations of active fires. These observations suggest that average monthly radiance products of NTL are contaminated by signals from forest fires, as also mentioned by NOAA. More investigation is required to study the effect of different time of passes of SNPP and MODIS on radiance values and other factors (e.g. camp fires) causing increase in radiance in forested areas. The study underscores the need to remove the effect of such temporary sources from even monthly average radiance NTL products of SNPP-VIIRS while studying the permanently lit areas for monitoring socio-economic development, particularly in forested areas.

1. INTRODUCTION

Forest fires are a bane to the environment. The flora, fauna, atmosphere, inhabitants and economics are deeply affected by these disasters (Hao *et al*., 1996; Gubbi, 2003). Practical control measures for forest fires are difficult due to inaccessibility, lack of timely information, lack of resources and effective time management. Tropical countries like India having large areas under forest cover, need specialized tools to monitor and manage these incidences. The management and conservation of forested areas can only be performed if the status of the forest area is maintained and updated regularly in spatial domain. Remote sensing when combined with Geographical Information System (GIS) can contribute in preparatory planning, control planning and damage assessment for pre-fire, during fire and post-fire phases. Nowadays these techniques are being operationally used by the Forest Departments in mitigating forest fires before they take a wild form (Chand *et al*., 2007; Badrinath *et al*., 2011).

As forest fires tend to continue from current day to the next day (Chand *et al*., 2006), *night-time light* (NTL) imagery have opened new doors for identification and mapping of fire locations. The earlier Defense Meteorological Satellite Program - Operational Linescan System (DMSP/OLS) imagery and the newer NASA/NOAA's Suomi National Polar-orbiting Partnership satellite - Visible Infrared Imaging Radiometer Suite (VIIRS) - Day and Night band (VIIRS/DNB) imagery are helping decision makers take necessary steps at targeted locations. Several global efforts have been made, including the Indian Forest Fire Response and Assessment System (INFFRAS), which report real-time forest fire information to stakeholders. The MODIS, NOAA/AVHRR and VIIRS forest fire products are well validated and widely used in real time forest fire management (Schroeder *et al*., 2014). The capability of DMSP-OLS and VIIRS-DNB sensors in detecting feeble radiances (of the order of 10^{-9} W/cm^2/sr) associated with flame front during night makes NTL imagery a vital tool in forest fire monitoring programmes (Cao *et al.,* 2014).

The NTL imagery have also been extensively used to study socio-economic dynamics (Bennett and Smith, 2017). This is enabled by development of algorithms which distinguish stable VNIR emissions (such as city and village lights) from temporary emission sources (such as fires, boats etc.) (Elvidge *et al*., 1997, 2001). Today, scientists around the world use stable NTL products made available in readily usable format by the National Oceanic and Atmospheric Administration – Earth Observation group (NOAA/EOG) on a regular basis. NOAA/EOG processes the night-time pass of VIIRS (time of pass at the equator is approximately 1.30 AM in descending mode) imagery for removal of effects due to cloud, lightening, lunar illumination and stray light. These daily images are then averaged for each month and are made available to the users as average monthly NTL radiance images. This process, however, does not take care of ephemeral emission sources such as lights from aurora, fires, boats, etc. (EOG, 2017).

DMSP/OLS did not have on-board calibration and thus the NTL imagery had limitations in inter-annual and long-term studies. The VIIRS/DNB data are calibrated and per pixel radiances ($nW/m^2/sr$) are available in the NTL imagery. This study aims to understand the impact of forest fires on night-time radiances. Monthly average radiance products from NOAA/EOG are studied in the densely forested Nilgiris and Kanyakumari districts of Tamil Nadu State of southern India.

2. STUDY AREA

The Nilgiris and Kanyakumari districts in the Tamil Nadu State of India form the study areas (Fig. 1). Tamil Nadu State is located in the southern part of India and constitutes about 3.96% geographic area of the country. Physiographically, the State can be divided into three major zones: coastal plains, central plateau and mountains (Eastern Ghats and Western Ghats). The recorded forest area in the Tamil Nadu State is 22,877 km^2, which constitutes 17.59% of geographic area of the State. Reserved forest, protected forest and unclassed forest comprise 84.75%, 9.54% and 5.71% of total forested area. About 66.5% of the Kanyakumari District and 100% of the Nilgiris District is under forest cover, based on forest cover fraction data of 2013 (5 km x 5 km grid) available in Bhuvan portal (www.bhuvan.nrsc.gov.in) considering non-zero forest cover fraction (Fig. 1).

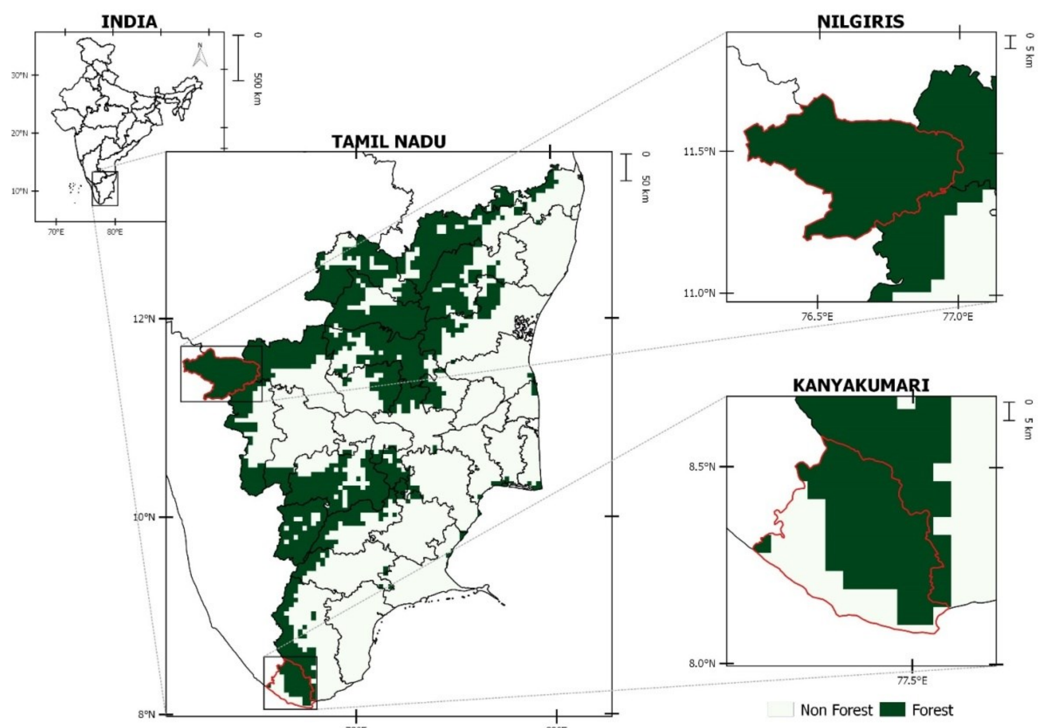


Figure 1: Location of the study area. Green colour shows the forest cover based on forest fraction data of 2013 (5 km x 5 km grid) available in Bhuvan portal (www.bhuvan.nrsc.gov.in) having non-zero forest cover fraction

3. MATERIALS AND METHODS

3.1 Data used

Table 1 provides the details of remote sensing data derived products that are used in this study. The VIIRS/DNB derived monthly NTL products from NOAA/EOG are used for the four pre-monsoon months (February to May) of 2014. The widely used MODIS derived active fire points data are used for the same period. The Bhuvan portal (Bhuvan, 2017), provides annual forest fraction cover maps over India, derived from Indian Remote Sensing Satellite (IRS) data. The areas which have non-zero forest fraction are masked as 'forest' (Fig. 1)

Table 1: Datasets used in the present study

Sl. No.	Name of Datasets	Product_id	Spatial Resolution	Temporal Resolution	Source
1	VIIRS NTL imagery	VIIRS	500 m	Monthly	(EOG, 2017)
2	Active fire points	MOD14	1 km	Daily	(MOD14, 2017)
3	Forest fraction	Forest Fraction Cover	5 km	Annual	(Bhuvan, 2017)

3.2 Methodology

Figure 2 shows the generalized steps followed to understand the impact of forest fires on night-time radiances. All the three datasets (Table 1) are pre-processed to bring to same spatial and temporal extent. They are then masked using the forest mask, prepared from Bhuvan data, to generate the subset for forest areas only. The spatially aggregated metric, Sum of Lights (SOL), is calculated for the forested areas of the two districts and related with the forest fire incidences. Next, on the points where MODIS data show active fires, the corresponding radiance values from VIIRS/DNB monthly composites are extracted and the percentage change in radiance and coefficient of variance (CV) for each pixel are calculated and studied with reference to incidences of forest fires. The percentage change in radiance is calculated the month of April (being the month of high fire incidences) taking February month as reference. CV is calculated as a ratio of the mean and the standard deviation from the monthly VIIRS images for the forested areas of both the districts. The change in radiance and CV are then analysed with reference to active fire points.

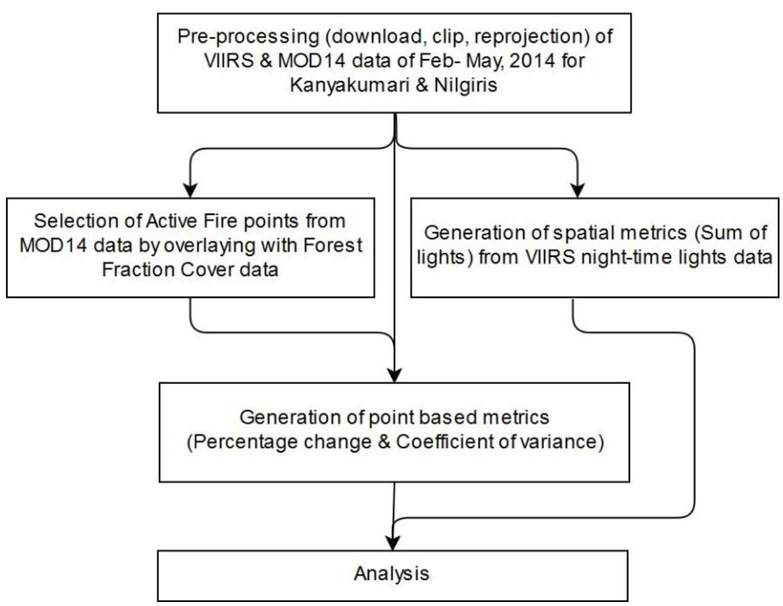


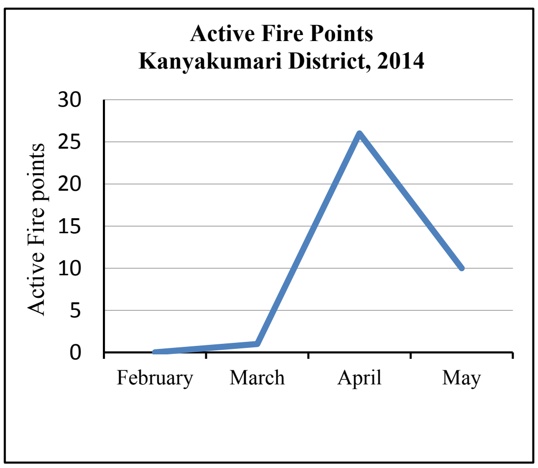
Figure 2: Generalised methodology used in the study

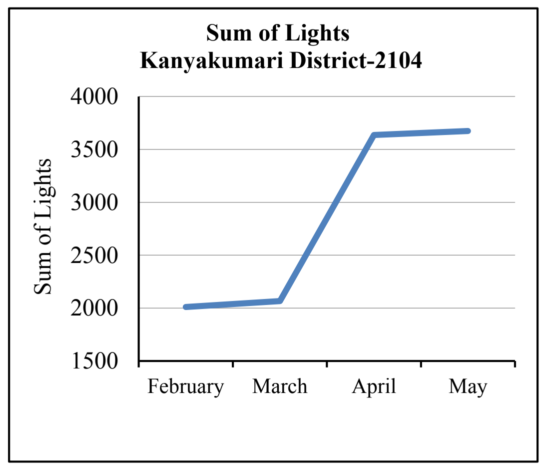
4. RESULTS AND DISCUSSION

4.1 Effect of forest fires on night-time radiances based on lumped statistic

Figure 4 show monthly active fire points, SOL and their correlation for Kanyakumari District. The number of fire incidences recorded in the month of April is highest among the four months. The SOL values also show significant increase in the months of April and May. The correlation coefficient (r) between the monthly SOL and number of fire incidences is found as 0.83. Similar results are obtained in case of forested areas of Nilgiris District (Fig. 5). The number of fire incidences in the Nilgiris District is highest in the month of March. The SOL increases considerably from February to March which increases slightly in April and then decreases considerably in May. The correlation coefficient (r) between the monthly SOL and number of fire incidences in the case of Nilgiris District is found as 0.66.

These observations indicate that increase in monthly radiances in the months of March and April is most likely due to occurrence of forest fires as the forest areas are uninhabited and temporary increase in night-lights due to human settlements does not logically appear to be a reason.





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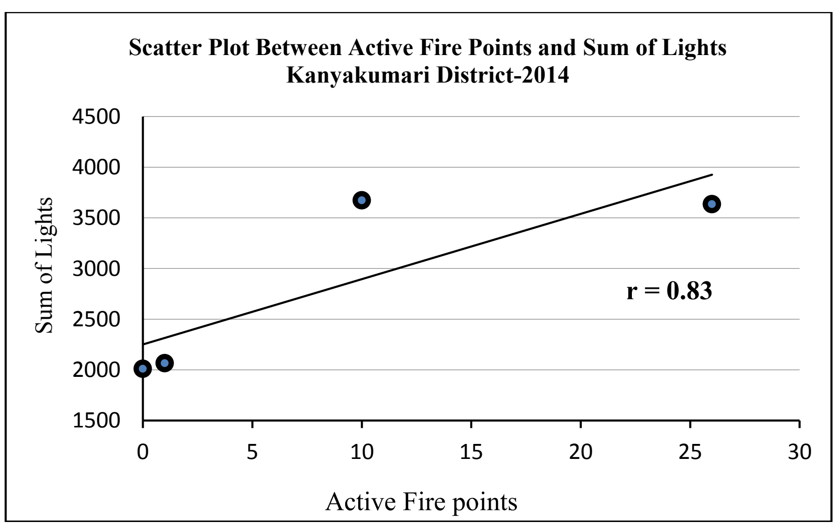

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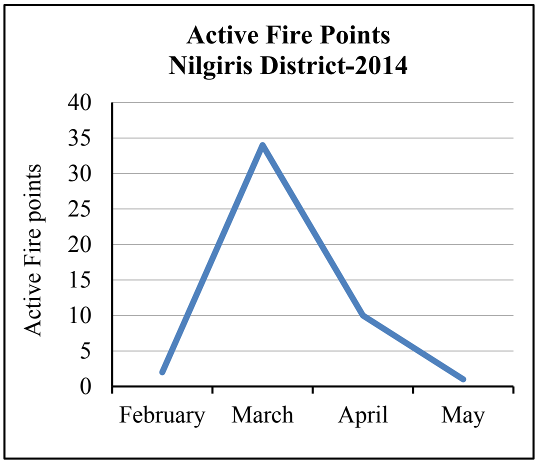
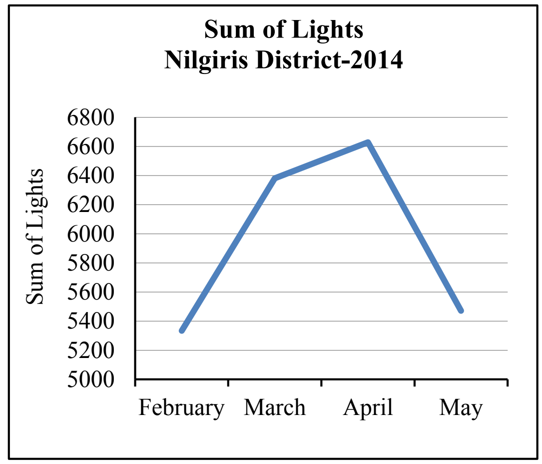
Figure 4: (a) Monthly active fire points as obtained from MODIS data, (b) monthly variation in SOL as observed from VIIRS/DNB data, and (c) relation between SOL and active fire points in Kanyakumari District



(a)



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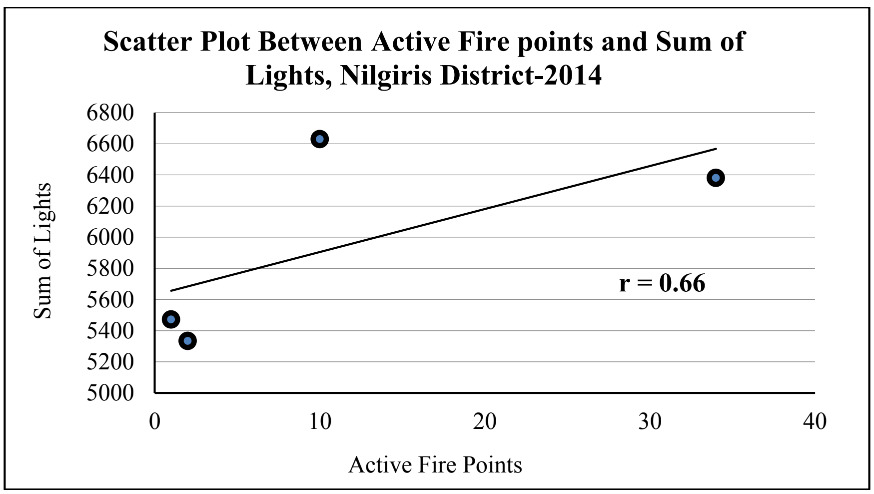

(c)

Figure 5: (a) Monthly active fire points as obtained from MODIS data, (b) monthly variation in SOL as observed from VIIRS/DNB data, and (c) relation between SOL and active fire points in Nilgiris District

4.2 Effect of forest fires on night-time radiances at fire locations

The spatial distribution of change in radiance (expressed in %) in the month of April taking February as reference is shown in figure 6. It is clear from this figure that majority of the active fire points of April fall in areas having high positive change in radiance. Conversely majority of the active fire points of February fall in areas having values below zero. The data on change in radiance values at fire locations are also depicted as box plots (Fig. 7). It is observed that median radiance value has increased by 28.5% in the Kanyakumari District; this increase is 14.8% in case of Nilgiris District. While there is less increase in median radiance value in the Nilgiris District as compared to the Kanyakumari District, but the radiance at many fire points have increased substantially in the Nilgiris District.

The spatial distribution of CV and the box plots for the two districts are shown in figure 8 and figure 9, respectively. It is observed from these figures that that majority of the active fire points in the April month fall in the zones having higher CV values.

Therefore, the point based metrics (change in radiance and CV) as well as spatial statistic (SOL) in the forested areas of both the districts suggest linkage with fire occurrences. The increase in radiance during night-time in forests can most likely be attributed to forest fires, as anthropogenic lighting in these uninhabited areas can generally be ignored.

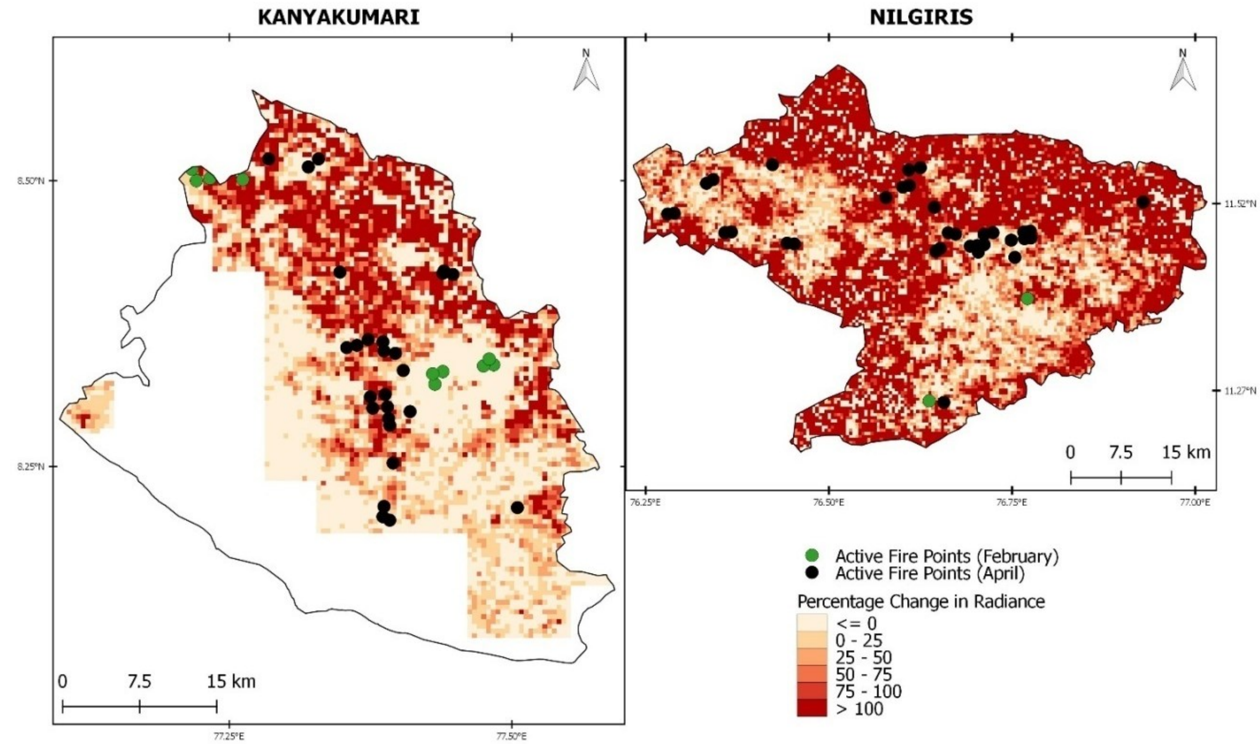

Figure 6: Spatial distribution of percentage change in radiance in the month of April with rerefence to February for (a) Kanyakumari District and (b) Nilgiris District. Active forest fire locations in February and April are shown as green and black dots

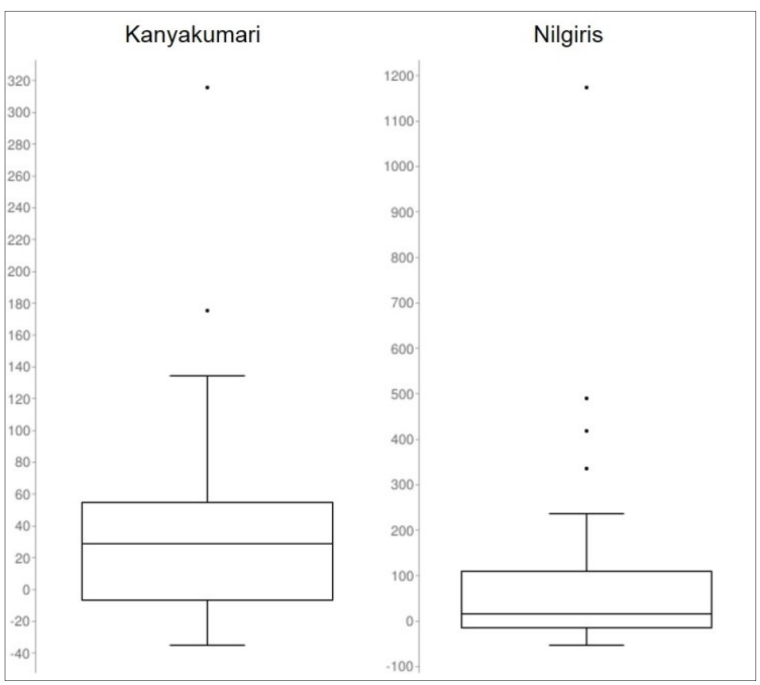

Figure 7: Box plot showing the percentage change in radiance for the active fire locations of April month in the Kanyakumari (n=26) and Nilgiris (n=35) districts

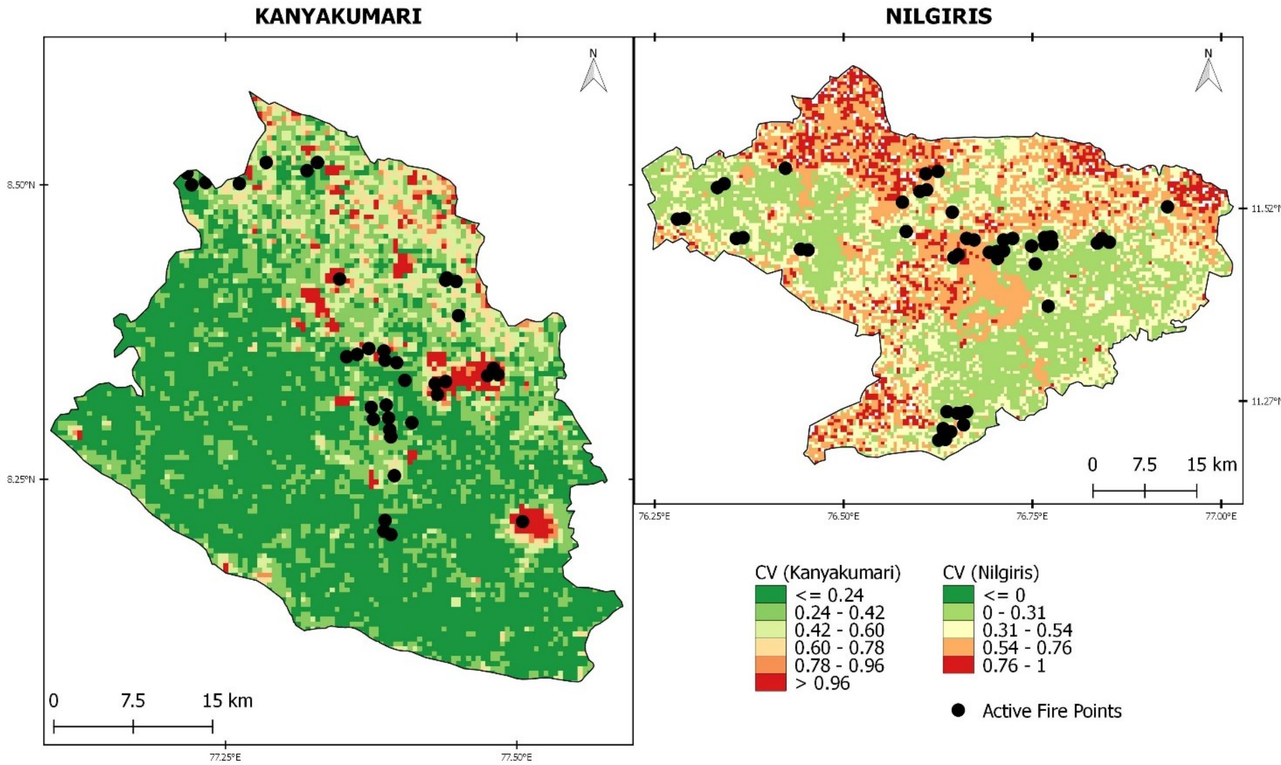

Figure 8: Spatial distribution of percentage change in radiance in the month of April with rerefence to February for (a) Kanyakumari District and (b) Nilgiris District. Active forest fire locations in the month of April are shown as black dots

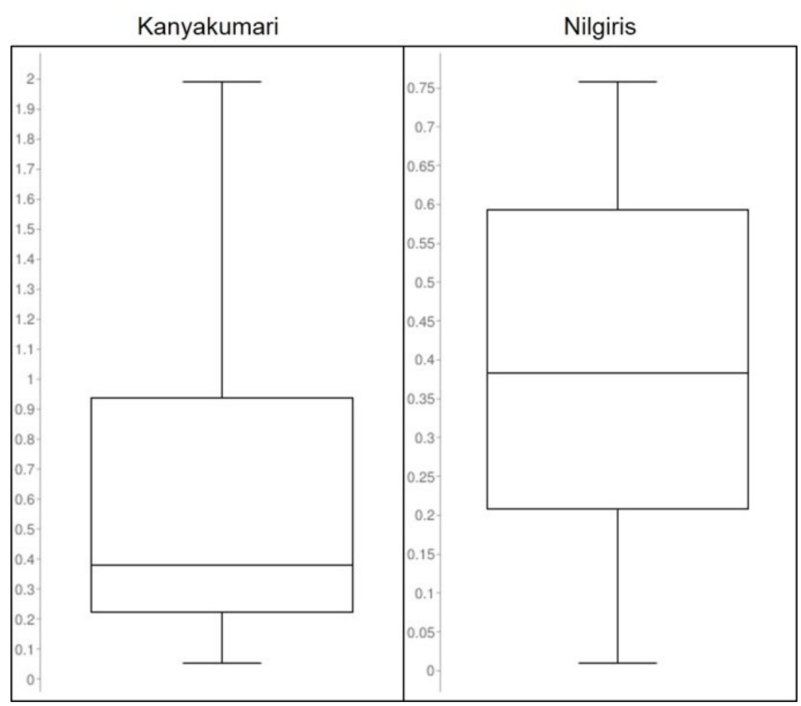

Figure 9: Box plot showing the CV of monthly radiances (February to May, 2014) for the active fire locations of the April month in the Kanyakumari (n=26) and Nilgiris (n=35) districts

5. CONCLUSIONS

The effect of forest fires on the monthly average radiances recorded in the VIIRS/DNB NTL imagery is studied here. It is observed that forest fire incidences in the months of March and April have resulted in an increase in the aggregated monthly radiances (considered in terms of SOL) in the forested areas of both the Kanyakumari and Nilgiris districts of Tamil Nadu (India). The number of active fire points correlate well with the monthly radiances. Point based metrics such as percentage change in radiance in the month of April and coefficient of variance in the pre-monsoon season for active fire locations also indicate increase in night-time radiances. Thus, the VIIRS/DNB average monthly NTL composites should be used carefully in the forested areas as there could be contamination from forest fires. Detailed analysis is, however, needed to quantify the extent of the said contamination. The effects of different time of pass of SNPP and MODIS on radiance values and other factors (such as camp fires and vegetation clearance), which can cause an increase in the night-time radiances, also need to be considered.

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